Examining the Sensitivity of Simulated Midlatitude and Tropical Mesoscale Convective Systems to Horizontal Grid Spacing

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Project Overview

Objective: *evaluate the resolution sensitivity of midlatitude and tropical MCSs—particularly the properties of convective updrafts and downdrafts—using an ensemble of real-data simulations with Δx ranging from 4 km to 125 m*

Experiment Design

WRF-ARW simulations were conducted for 10 midlatitude and tropical mature-phase MCS events that passed over the ARM sites in the U.S. Southern Great Plains [SGP] and Amazon Basin [MAO] during the GoAmazon2014/5 field experiment

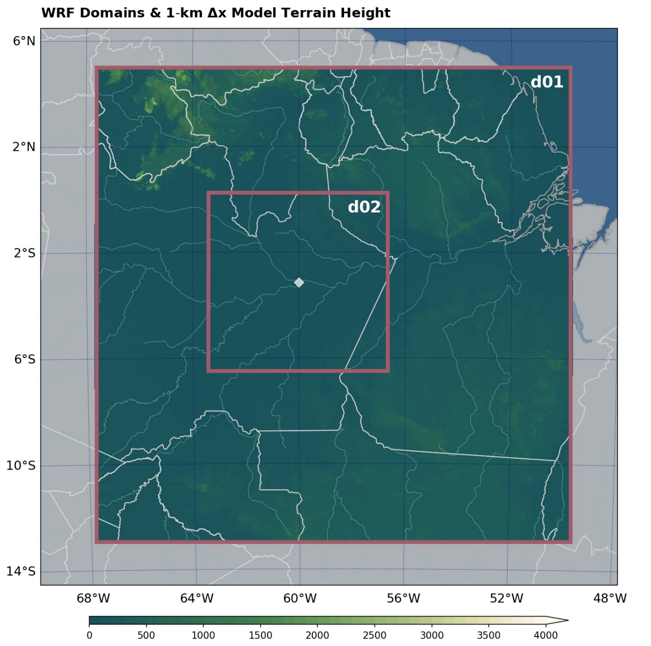
- *For each case:* Δx = 4 km, 2 km, 1 km, 500 m, and 250 m
- *For two cases in each regime:* Δx = 125 m
- *Common vertical grid:* 96 levels; average Δz ≈ 215 m

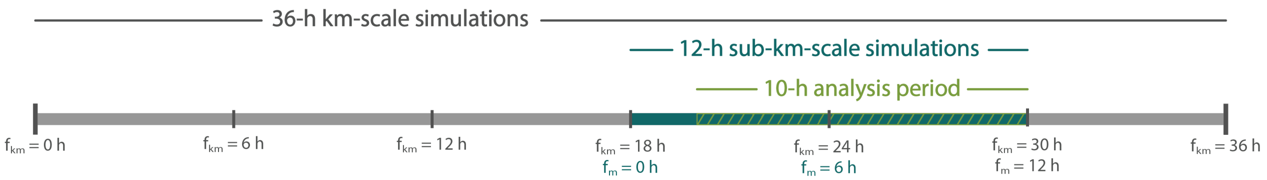
Initial and Boundary Conditions – ERA5; updated hourly

Parameterizations – **Longwave and Shortwave Radiation:** RRTMG; **PBL [Δx ≥ 500 m]:** YSU; **Subgrid-scale Turbulence [Δx ≤ 250 m]:** 1.5-order TKE closure; **Microphysics:** Thompson; **Land Surface Model:** Unified Noah

Simulations of these events were previously described in Prein et al. [2022], Earth and Space Science, and Ramos-Valle et al. [2023], JGR Atmospheres

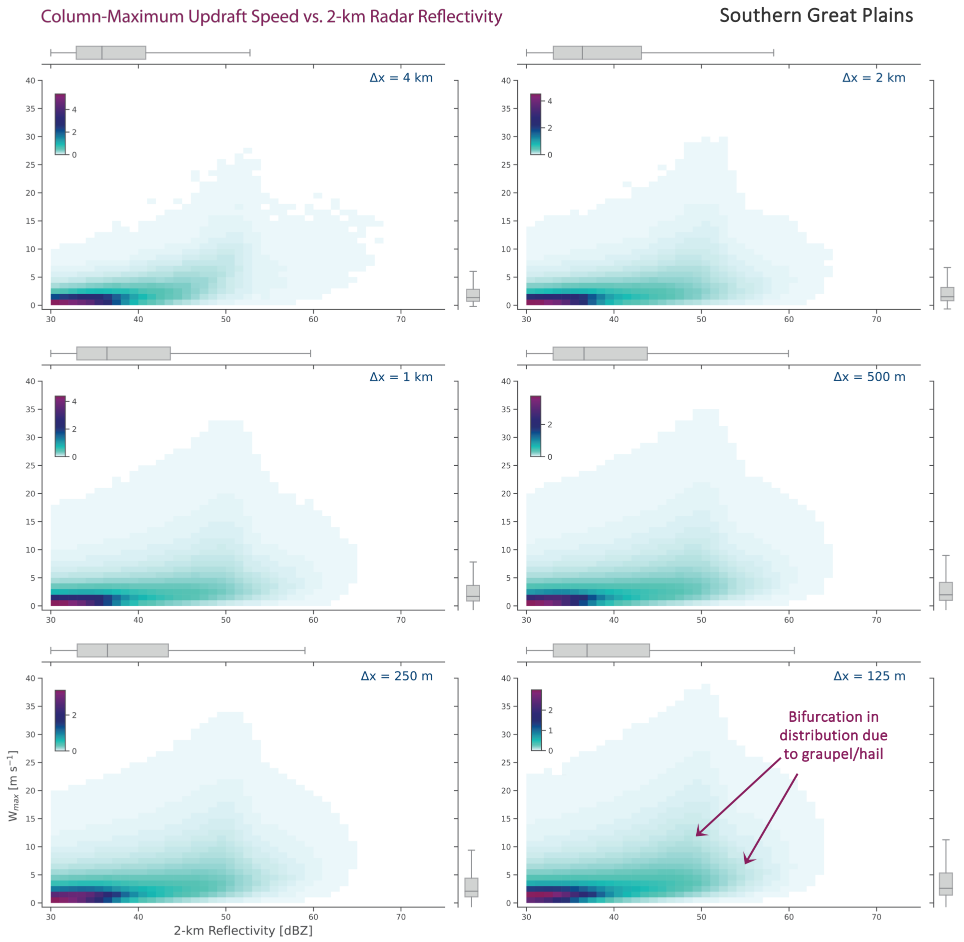
SGP Events	MAO Events
31 May 2012	1 April 2014*
15 June 2012*	17 September 2014
9 May 2013	4 October 2014
5 June 2013	18 October 2014
17 June 2013	17 November 2014
2 June 2014	10 December 2014
5 June 2014	28 March 2015
12 June 2014*	12 April 2015
28 June 2014	21 June 2015
10 July 2014	6 November 2015*

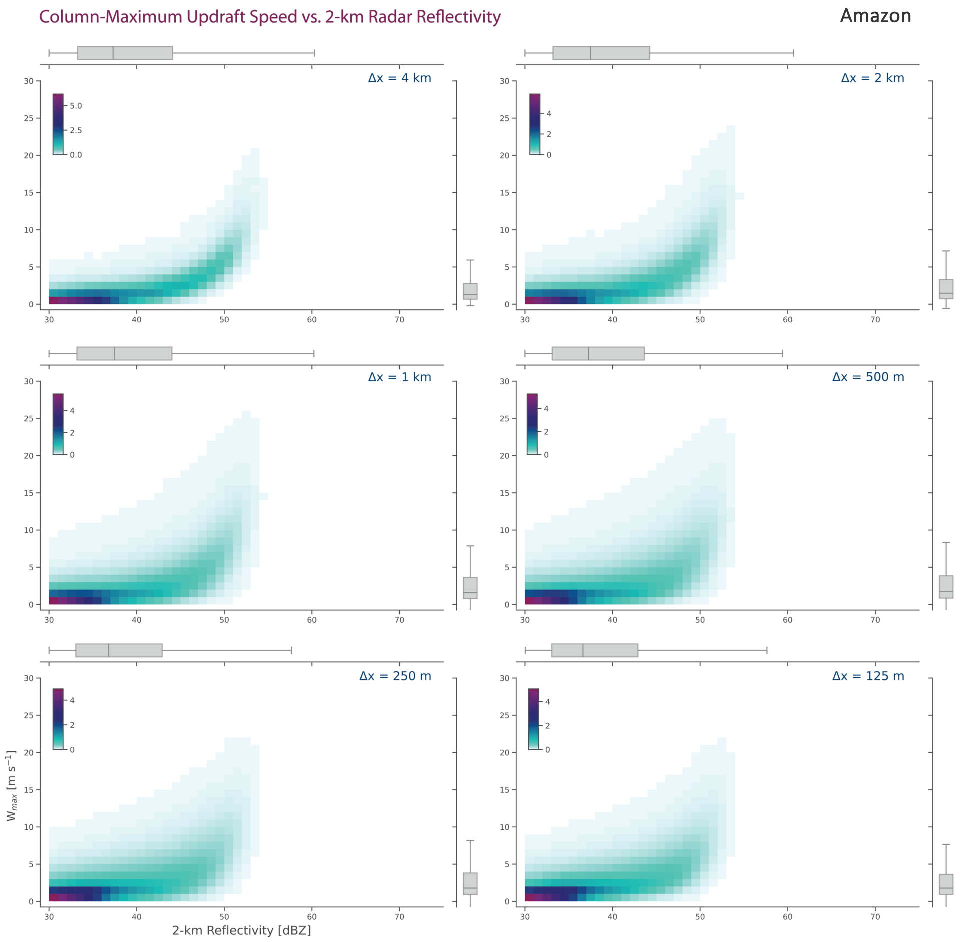




For more details, see Poster #47

Relationship Between Low-Level Reflectivity and Updraft Intensity



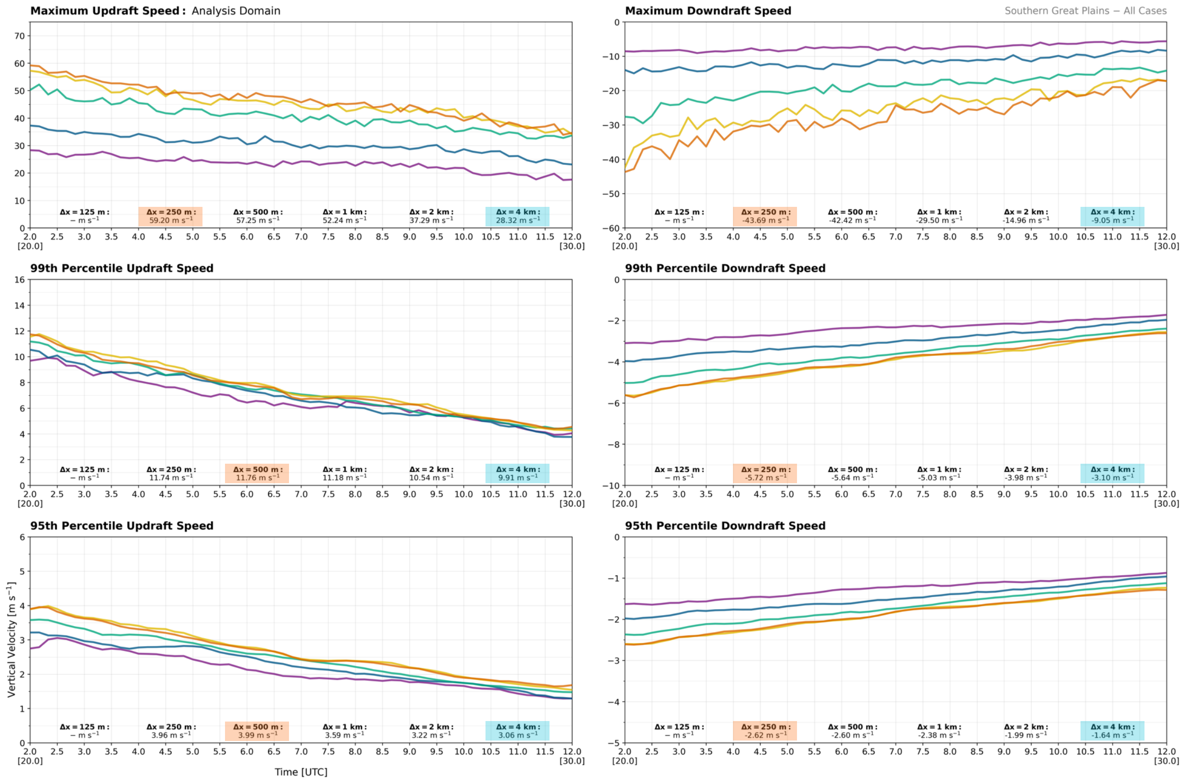


- In the **Southern Great Plains**, a bifurcation is evident at reflectivity ≥ 50 dBZ, whereas the **Amazon** exhibits a clearer relationship between reflectivity and column-maximum updraft speed
  - *This trend is also present when evaluating column-maximum downdraft speed*
- Bifurcation in SGP is likely due to the inflation of reflectivity values by graupel/hail
  - *Essentially no graupel makes it below 2 km AGL in the Amazon*

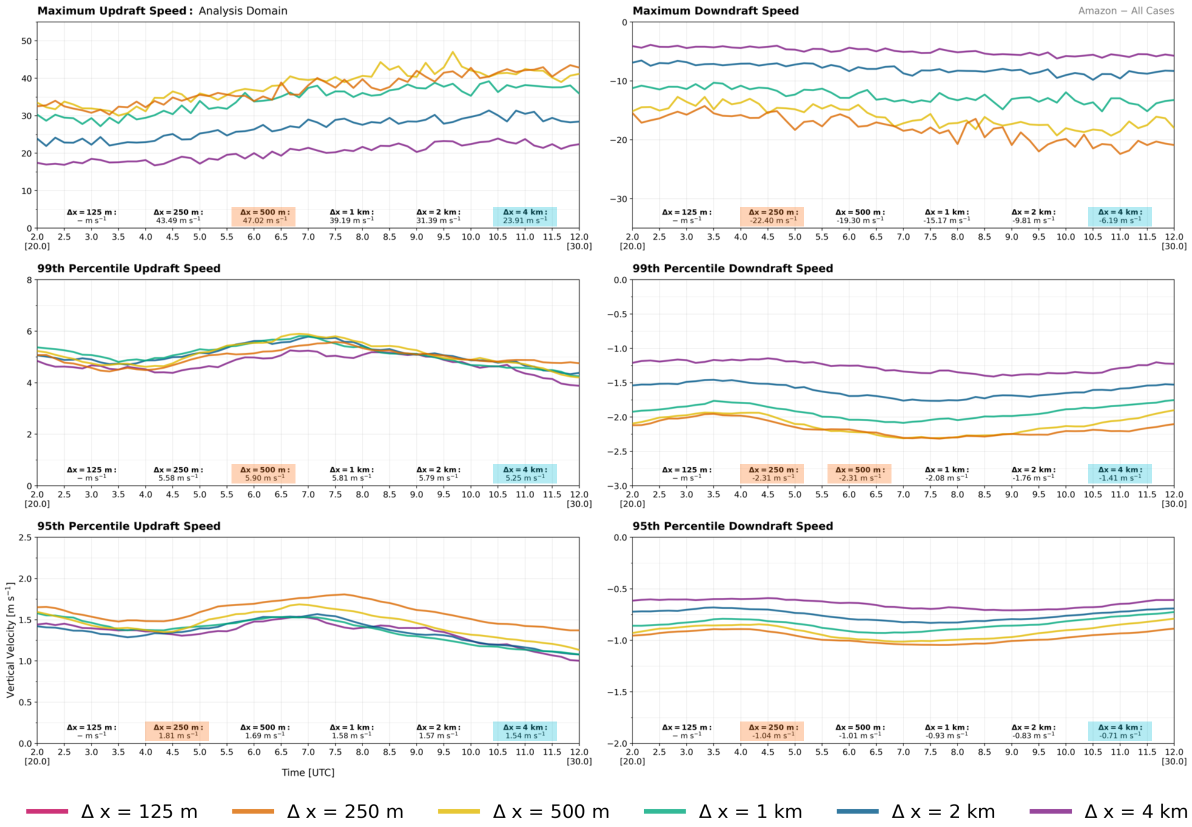
For more details, see Poster #47

Vertical Velocity Extrema as a Function of Δx

Southern Great Plains: *N = 10*



Amazon: *N = 10*



In the Southern Great Plains:

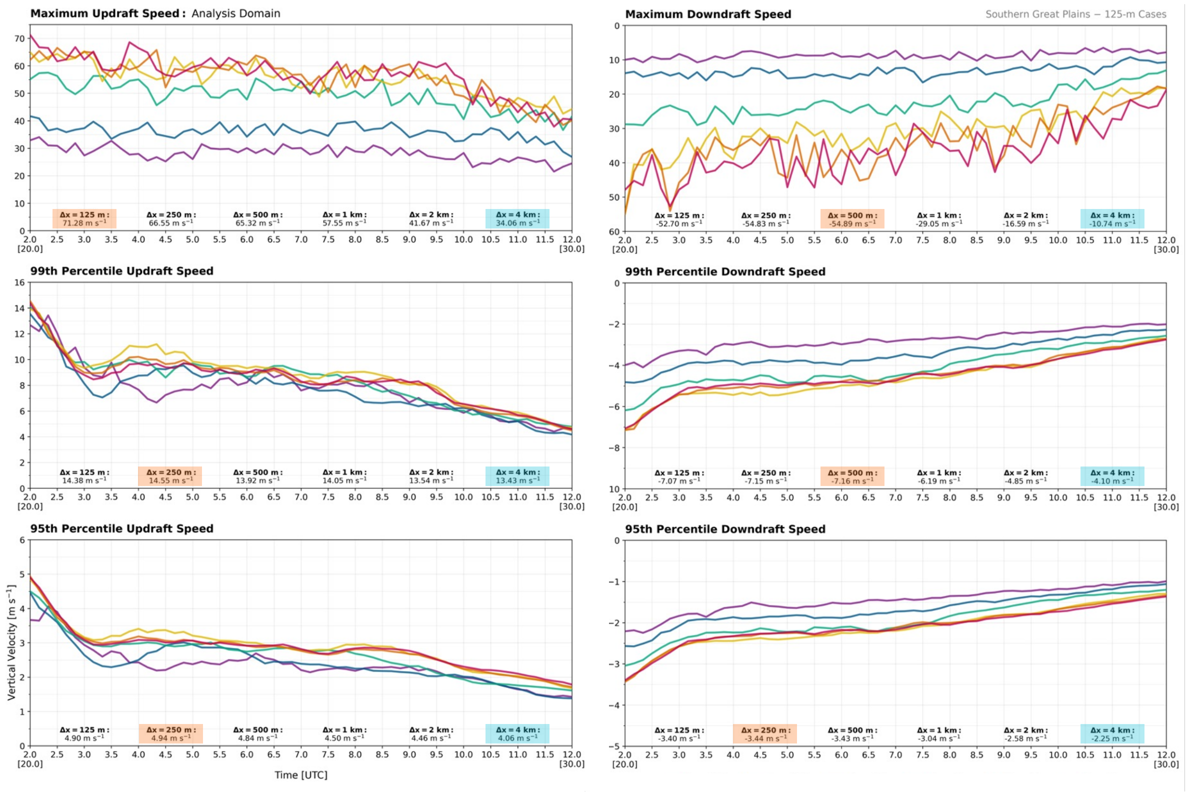
- Excellent agreement between 250-m and 500-m simulations for strongest updrafts and downdrafts, with slightly higher absolute maxima in the 250-m simulations *on average*

In the Amazon:

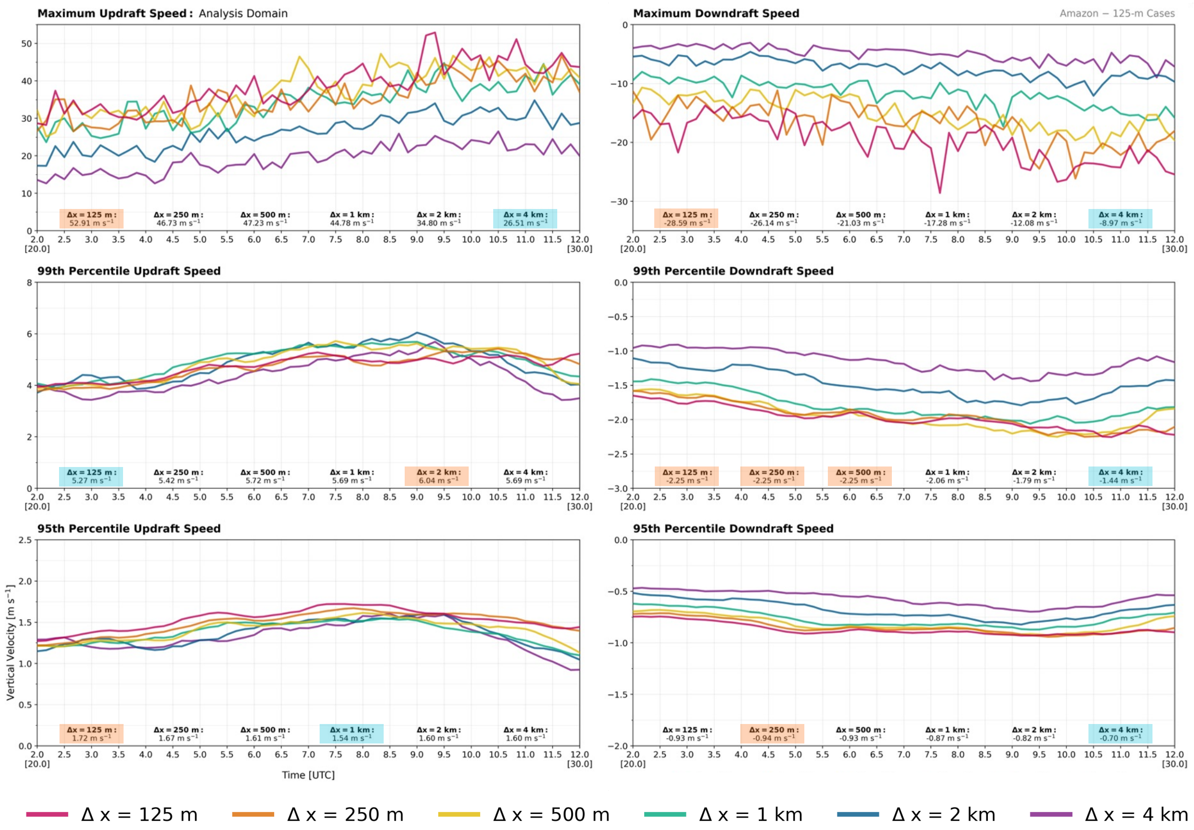
- Comparatively larger difference between 250-m and 500-m simulations, but still overall good agreement

Vertical Velocity Extrema as a Function of Δx

Southern Great Plains: *N = 2*



Amazon: *N = 2*



In the Southern Great Plains:

- Compared to 250-m simulations, 125-m simulation often produces slightly weaker updraft and downdraft maxima
  - *Perhaps due to more entrainment-driven dilution? Relationship to downdraft intensity is less clear…*

In the Amazon:

- Compared to 250-m simulations, 125-m simulation produces slightly stronger 95% and 99% vertical motions and clearly produces larger absolute velocity maxima
  - *Narrower updrafts better resolved? Less adverse effects from entrainment in moist environment?*

For more details, see Poster #47

Next Steps and Considerations…

- ## Ongoing/future work:
  - More analysis on simulated convective cores and draft characteristics [e.g., echo-top height, intensity, size, vertical structure, mass flux, etc.]
  - Comparing results from native grid spacing analyses to those conducted on fields coarse-grained to Δx = 4 km
  - Assessing how simulations compare to radar wind profiler [RWP] observations

- ## Some considerations for connecting observations and simulations:
  - Limitations of point measurements — *are we observing the region of strongest vertical motions?*
  - Current ground-based profiling observations that permit reliable vertical velocity estimates in MCSs have coarser horizontal resolution than LES output — *how can we observe the finer-scale turbulence depicted in LES?*
  - Vertical velocity retrieval uncertainties, especially within the melting layer, where convective downdrafts often originate
  - Andy and Dié's ongoing work comparing simulated RWP output and vertical cross sections of instantaneous model fields illustrates some challenges of using point observations to validate simulations

Comparisons of observed and simulated mean vertical velocity profiles as a function of echo-top height [ETH] – Amazon

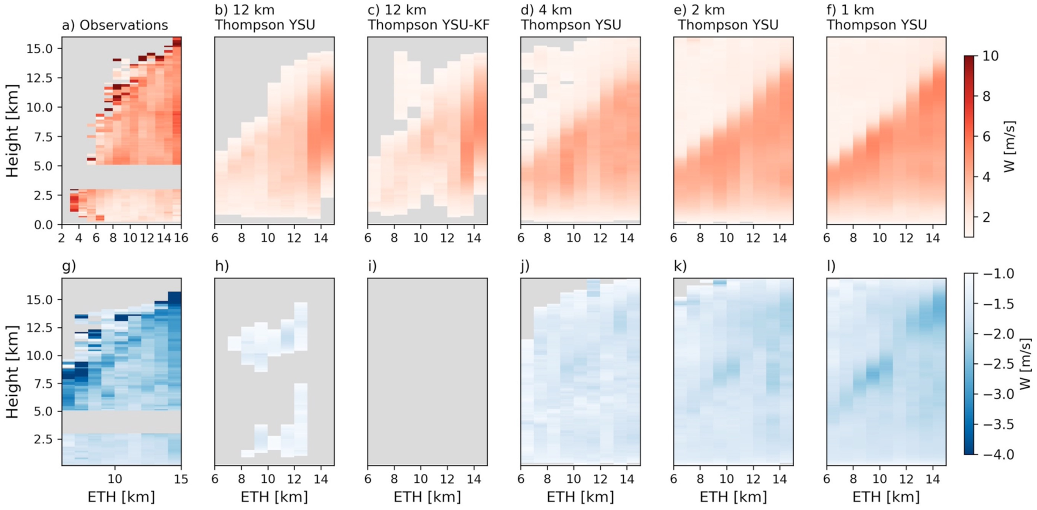
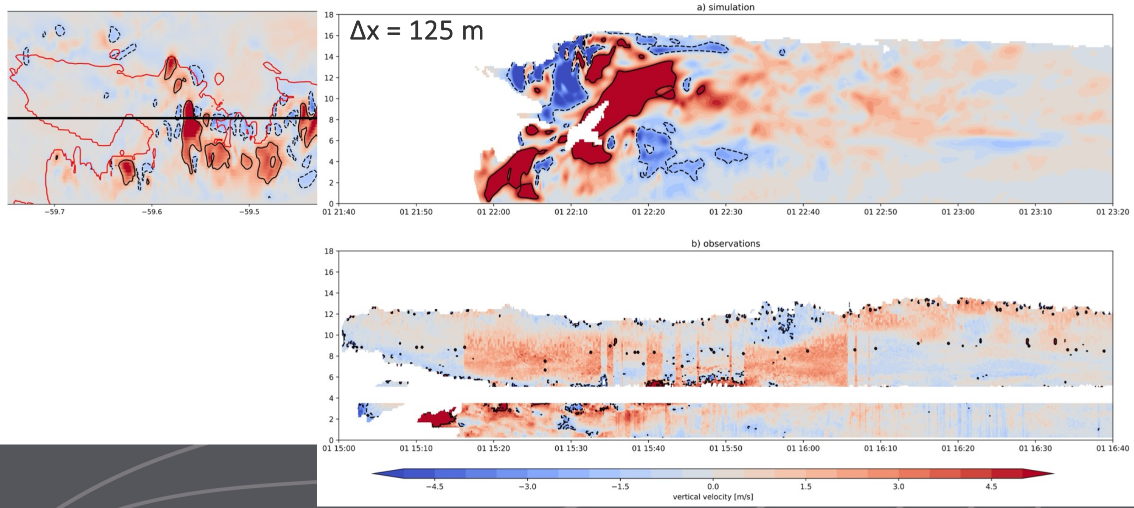


Fig. 11 from Ramos-Valle et al. [2023], JGR Atmospheres

Vertical cross section, simulated RWP output, and RWP observations

Amazon – 1 April 2014, 1500 UTC



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